may be most cost-effective in these higher-risk categories, again because the prevalence will be higher and costs associated with renal failure potentially avoided if clinical action can be undertaken to prevent further renal deterioration and eliminate the need for dialysis.

Finally, our composite risk score and guide may have utility in informing patients and their families about OHT and its associated risks. More specifically, the guide in Table 3 can be used to give a realistic impression of what the risks are of needing dialysis at least temporarily in the postoperative period. Although our score is a predictor of acute renal failure and not necessarily the need for chronic dialysis, the former is certainly a risk factor for the latter. In a future study, it may be important to evaluate the specific rates of chronic dialysis stratified by acute renal failure risk category, because ongoing dialysis would certainly affect a patient's quality of life and may therefore be important to disclose in the consenting process.

Study Limitations

An important limitation of our study is that other variables that may affect rates of renal failure are not available in the UNOS database and therefore are unable to be included in our risk index. These variables include the use of nephrotoxic medications, perioperative fluid balance, intraoperative and postoperative bleeding, and episodes of perioperative hypotension, to name a few. In addition, the decision to dialyze a patient can vary between providers and between institutions. There is a possibility that a patient who was categorized as having renal failure requiring dialysis in our study may not have been dialyzed with a different provider or at a different institution. Another limitation is that our analysis was confined to the postoperative period, but there is a possibility that an OHT recipient may have been readmitted after hospital discharge and subsequently dialyzed. Finally, our analysis is limited to renal failure requiring dialysis and did not evaluate less severe forms of acute kidney injury, because these data are not available in the UNOS registry.

CONCLUSIONS

This study derived and validated a composite risk index for postoperative acute renal failure requiring dialysis after OHT using data from 14,635 patients. The risk score was then used to construct a simple clinical guide to provide clinicians the ability to prospectively estimate postoperative renal failure risk in OHT recipients. The risk index and clinical guide may have potential applications in guiding the perioperative management of OHT recipients and in clinical research stratification. Because postoperative acute renal failure is a powerful predictor of mortality, other morbidity, and resource use, continued improvement in preventing its occurrence and optimizing its management is essential.

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Discussion

Dr Mark Slaughter *(Louisville, Ky)*. In the preoperative variables that were evaluated, it appears as though transpulmonary gradient and pulmonary vascular resistance were not included. These can affect donor right ventricular function and lead to low-flow output situations and poor renal perfusion. Were these variables not available, and what influence would they have on the risk score if included?

Dr Kilic. Some hemodynamic variables are inconsistently recorded in the UNOS database. Those variables that had more than 20% missing data were excluded as potential risk factors in our score calculation. Other hemodynamic variables did not meet entry criteria for our multivariable model. The other item with the hemodynamic parameters is exactly when they're being measured. In the UNOS database, they are measured as close to

the heart transplantation as possible, which I think is a reliable measure. However, again because of the high percentage of missing data or the lack of predictive power, those variables were excluded.

Dr Slaughter. Similarly, for preoperative variables, I'm surprised that status 1A and 1B were not included. You would think a higher-risk individual might be at higher risk for renal failure.

Dr Kilic. We looked at each component of what would determine a patient to be UNOS status 1 or 2. So bridging with ventricular assist devices, extracorporeal membrane oxygenation, patients on inotropes, all those variables were looked at and evaluated in the analysis. Some of those variables were significant in univariate analysis; however, after our statistical methodology, they did not meet inclusion criteria for the final multivariable model.

Dr Slaughter. Although mentioned as limitations, operative events that result in bleeding, transfusion, hypotension, and decreased donor organ function will significantly affect postoperative renal function. Do you think your risk score is just a surrogate marker for those patients who will not tolerate perioperative complications?

Dr Kilic. That's an excellent point, and it is something we can't control for because those variables are not present in the UNOS database. So it's difficult to tell. It may very well be a surrogate.

Dr Slaughter. The concern would be if you have a patient with a predicted 20% risk. The question is, are you going to exclude that patient? But if you have a perfect operation, once again, the odds are the patient probably will be okay.

Last, along these lines, will the risk score change your approach to managing patients? An example is a patient with decreased renal function, diabetes, and age more than 60 years, thus a high-risk patient for post-transplant renal failure; should that patient automatically get a ventricular assist device to demonstrate improvement in renal function before receiving a transplant that might lead to better organ allocation?

Dr Kilic. That's one of the potential applications of this risk score. Other applications would be looking at induction therapy, for instance. Approximately 50% of transplant recipients receive induction therapy, and it would be interesting to look at those patients who are at very high risk for renal failure preoperatively whether or not induction therapy would be more useful or not. These are all potential clinical applications and certainly deserve more attention.

Dr Robert Higgins *(Columbus, Ohio)*. Yes, I agree, Dr Kilic, a very articulate description of a complicated issue. I guess the question I had in this risk-adverse world, knowing that we are trying to optimize outcomes for these heart transplant recipients, is should we now use this tool as a discriminator of patients who are at risk for renal failure in the perioperative period? Can creatinine clearance less than 30 be a marker for impending renal failure postoperatively? Maybe they shouldn't even be considered for heart transplant alone but rather heart-kidney transplantation, which would then allow you to mitigate the effects of whatever risk factors or variables are being played out here.

Dr Kilic. When we're talking about patient selection, which patients should undergo heart transplantation, we should focus on models that are looking at postoperative or 1-year mortality risk. Renal failure is a strong predictor for mortality, but there are other components that certainly contribute to overall mortality risk.

The utility of this score is to specifically tailor certain aspects of postoperative management and in terms of clinical research stratification. In terms of being a score that we look at for determining patient selection, again, I think models that are aimed at measuring risk of overall mortality are the models we should look at for that.

Dr Higgins. Yes, this may be a tool that would be effective for a lot of people.

Dr Thoralf Sundt *(Boston, Mass)*. My question relates to having sat for many hours in transplant selection conferences agonizing over whether the patient ought to have a heart or a heart-kidney. How many times have we had that discussion? The cardiologist or nephrologist says, ''Oh, the kidneys will get better,'' and sometimes you say it too.

Are you able to look within your own institutional database at those patients who had dodgy renal function preoperatively and separate those who did or did not get better and use this score to distinguish them? Is this actually applicable to the related question, will somebody with preoperative renal failure get better after a transplant or not?

Dr Kilic. Yes. Again, unfortunately, the UNOS database is limited in terms of the amount of postoperative data it has. Renal failure is simply coded as whether it's present or not, and that's only in cases where dialysis is needed. But I agree, looking at a single institution series where you have more clinical data available, including postoperative creatinine levels and other markers of renal failure, would be very interesting.

Dr Sundt. That's where you'd need to do it, in your own database. Thanks.

Dr Glenn Whitman *(Baltimore, Md)*. We too suffer every Tuesday afternoon with the dilemma of doing an isolated heart transplant versus a dual-organ transplant, pulling the kidney with the heart. Or, if we do not do a dual transplant, should we oversize because of worry about right ventricular failure, elevated central venous pressure, and postoperative renal function. But we can't do that study Dr Sundt just mentioned because we already use induction therapy selectively in patients who we think are going to have a high risk of renal insufficiency. Induction therapy is expensive, so we do not use it uniformly, but when someone is at high risk, we use it.